A LIGHT-WEIGHT INFLATABLE HYPERSONIC DRAG DEVICE FOR PLANETARY ENTRY

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ABSTRACT

The author has analyzed the use of a light-weight inflatable hypersonic drag device, called a ballute, for flight in planetary atmospheres, for entry, aerocapture, and aerobraking. Studies to date include Mars, Venus, Earth, Saturn, Titan, Neptune and Pluto, and data on a Pluto lander and a Mars orbiter will be presented to illustrate the concept. The main advantage of using a ballute is that aero deceleration and heating in atmospheric entry occurs at much smaller atmospheric density with a ballute than without it. For example, if a ballute has a diameter 10 times as large as the spacecraft, for unchanged total mass, entry speed and entry angle, the atmospheric density at peak convective heating is reduced by a factor of 100, reducing the peak heating by a factor of 10 for the spacecraft, and a factor of 30 for the ballute. Consequently the entry payload (lander, orbiter, etc) is subject to much less heating, requires a much reduced thermal protection system (possibly only an MLI blanket), and the spacecraft design is therefore relatively unchanged from its vacuum counterpart. The heat flux on the ballute is small enough to be radiated at temperatures below 800 K or so. Also, the heating may be reduced further because the ballute enters at a more shallow angle, even allowing for the increased delivery angle error. Added advantages are less mass ratio of entry system to total entry mass, and freedom from the low-density and transonic instability problems that conventional rigid entry bodies suffer, since the vehicle attitude is determined by the ballute, usually released at continuum conditions (hypersonic for an orbiter, and subsonic for a lander). Also, for a lander the range from entry to touchdown is less, offering a smaller footprint. The ballute derives an entry corridor for aerocapture by entering on a path that would lead to landing, and releasing the ballute adaptively, responding to measured deceleration, at a speed computed to achieve the desired orbiter exit conditions. For a lander an accurate landing point could be achieved by providing the lander with a small gliding capacity, using the large potential energy available from being subsonic at high altitude. Alternatively the ballute can be retained to act as a parachute or soft-landing device, or to float the payload as a buoyant aerobot. As expected, the ballute has smaller size for relatively small entry speeds, such as for Mars and Titan, or for the extensive atmosphere of a low-gravity planet such as Pluto. Details of a ballute to place a small Mars orbiter and a small Pluto lander will be given to illustrate the concept. The author will discuss presently available ballute materials and a development program of aerodynamic tests and materials that would be required for ballutes to achieve their full potential.
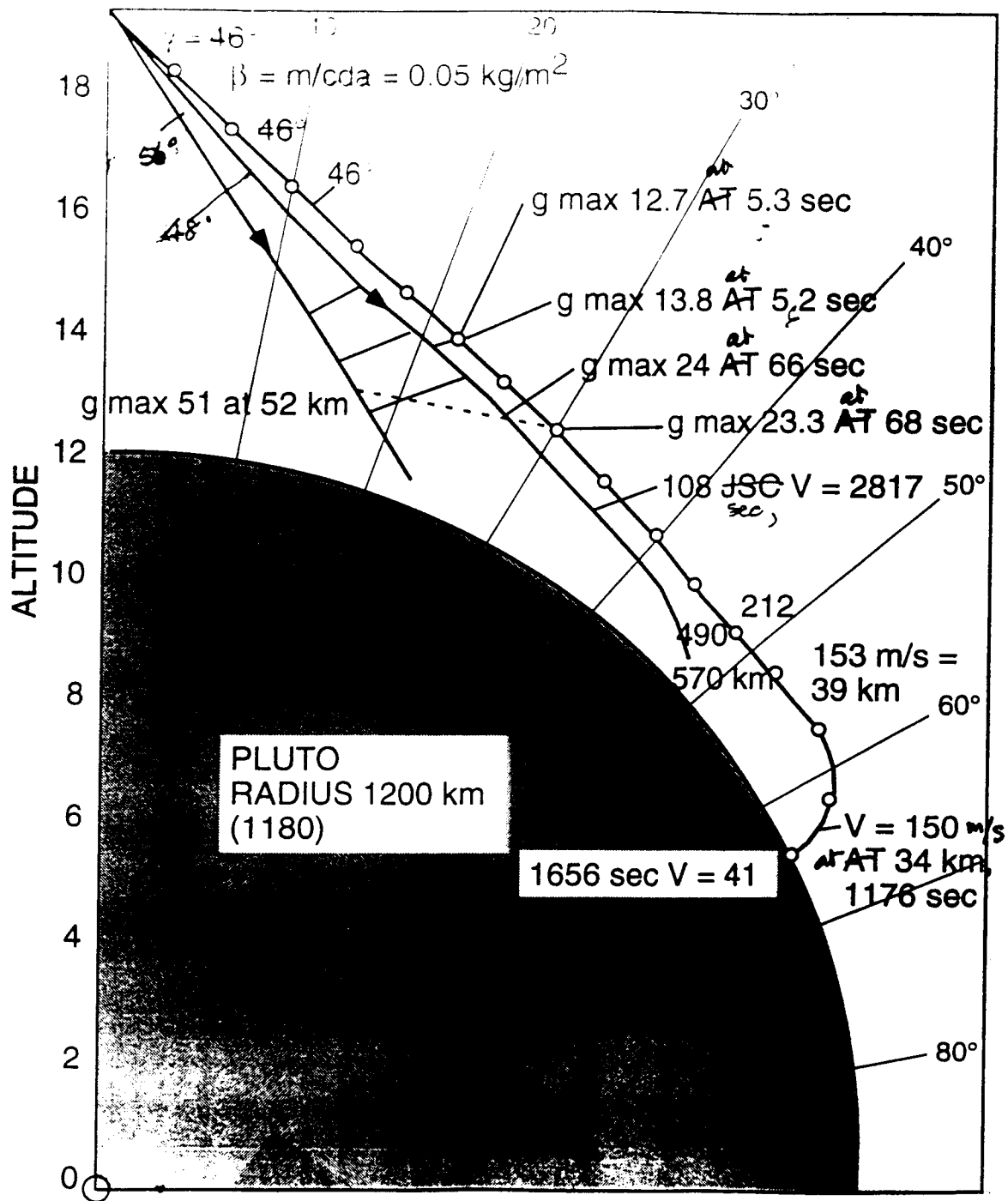
Fig. 8. Entry trajectories at Pluto for entry angles 46,48 and 56 deg, entry speed 15 km/s, m/CdA = 0.05 kg/m2.